Effect of moisture cycling on truss-plate joint behavior

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Abstract

The structural performance of wood trusses, which are now commonplace in light-frame construction, is dictated in part by the mechanical properties of the truss-plate joints. However, little information exists quantifying the effect of environmental conditions on truss-plate joint properties. The main objective of this paper was to quantify the effect of moisture cycling on the mechanical properties of truss-plate joints. A secondary objective was to evaluate the possibility of retarding the degenerative effects of moisture cycling by means of an adhesive applied to the teeth of the truss plate immediately before assembly. The results indicate that mild moisture cycling decreases truss-plate joint strength and stiffness by approximately twice that of specimens subjected to a constant moisture content. More severe moisture cycling accelerated this decrease by a factor of about three. Addition of an adhesive to the teeth decreased plate backout and increased the mechanical properties of the truss-plate joints. The increase in initial stiffness caused by the adhesive was minimal after moisture cycling, and the improvement in ultimate load remained substantial even after eight severe moisture cycles.

Light-frame construction has been moving away from the complete on-site assembly practices of the 1960s and 1970s and toward assembly of prefabricated sections. Hundreds of millions of trusses have been constructed in the past two decades in such structures as residential, commercial, and farm buildings. Parallel floor trusses and roof trusses with pitched top chords are now commonplace, with roof trusses representing the majority of the low-rise residential roof market. The joints of these all-wood trusses are connected almost exclusively using light-gauge steel plates with die-punched teeth, commonly referred to as truss plates. Truss plates are proprietary, with different sizes, types, and assemblies. However, they exhibit similar structural properties, making it possible to assign design values based on their mechanical behavior.

Recommended design values for truss members are dictated primarily by the materials composing the truss, the type of truss, and the expected loading during the life of the truss (26). The design plan laid out by architects and engineers for a particular structure generally dictates the type of trusses that will form the framework of the roof and floor systems. The required mechanical properties of the trusses are determined by defining the overall lifespan of the structure and by the loading as prescribed by local building codes. The truss manufacturer engineers the trusses based on required truss mechanical properties that meet or exceed current Truss Plate Institute (TPI) design values.

Truss performance is in most cases a reflection of the properties of the joints (31). Failure of truss systems occurs primarily at the joints because of stress concentrations, whereas large deflections in truss systems are generally the result of small joint displacements (22). Thus, evaluation of truss performance must begin with an understanding of the mechanical behavior of truss-plate joints.

In recent years, models of truss-plate joint behavior based on finite element analysis (3,8) and beam-on-inelastic-foundation theory (9,11) have been developed that define the static structural behavior of wood members and truss plates based on mechanical properties. However, both models concentrate on the fundamental mechanisms of stress transfer and ignore secondary variables such as load duration and cyclic fluctuations of wood moisture content (MC).

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TABLE 1. — *Illustrative summary of experimental design and number of replicates within each cell of the two randomized blocks.*

No. of cycles	No adhesive			Adhesive		
	MC moisture range			MC moisture range		
	12%	9% to 15%	5% to 19%	12%	9% to 15%	5% to 19%
0	10	10	10	10	10	10
1	10	10	10	10	10	10
2	10	10	10	10	10	10
4	10	10	10	10	10	10
8	10	10	10	10	10	10

Trusses are often found in the most environmentally volatile areas: attics and basements. Joist and rafter MC in these environments has been shown to fluctuate seasonally by anywhere from 10 percent (5,6) to as much as 18 percent (2,4,24). Even trusses subject to sheltered outdoor conditions experienced MC values that ranged from 10.6 to 15.5 percent over a 10-year period (31). This type of moisture cycling can significantly decrease truss performance. Unfortunately, the effect of moisture cycling has not been quantified. As a result, design values have been adopted that are conservative due to the limited data available. This makes for inefficient use of lumber whose mechanical properties are continually decreasing.

A workshop on structural wood research (13) identified long-term response to loading and variable environment as a research topic of high priority. Although moisture cycling has been shown to significantly affect mechanical properties of nailed joints (20), limited data exist that relate environmental conditions and truss-plate joints. In one study, truss-plate joints made of laminated veneer lumber and pine and subjected to an outdoor environment for 1 year showed a substantial decrease in stiffness and strength (19). The decrease in mechanical properties was due in part to "plate backout," a phenomenon in which the truss plate backs out of the wood members because of shrinking and swelling stresses. Plate backout significantly weakens the interfacial contact between the truss plate teeth and wood. Plate backout has also been observed in other studies (10,21,27).

Several studies have evaluated the effect of changing MC under a constant load for timber connectors (7,14,16-18,29). The results of these studies share one common theme: the combined effect of changing environment and loading significantly decreases truss stiffness. In most cases, strength was also significantly reduced. However, the research neither quantified the effect of moisture cycling on stiffness or strength nor defined the level at which moisture cycling proved significant.

The lack of quantifying data regarding environmental and loading effects presents a difficulty in truss design. Design specifications for duration of loading based on the Madison Curve are available from TPI (26). The effect of moisture cycling is compensated for by dividing the average load of 1) five moisture-controlled specimens (MC = 15% ± 4%) by 3.0, or 2) five moisture-response specimens (MC = 15% assembly, then 7%, then greater than 10%) by 2.5. Adequate understanding of environmental variables on truss-plate joint behavior is necessary to assign design values for truss manufacture.

Thus, the primary objective of this study was to quantify the effect of fluctuations in wood MC on truss-plate joint behavior. Specifically, this study compared the effect of severity and number of moisture cycles with truss-plate backout, joint stiffness, and joint strength. A secondary objective was to investigate maintaining interfacial integrity of truss-plate teeth and wood by applying an epoxy adhesive at the interface and noting the changes in truss-plate joint mechanical behavior.

Materials and procedure

Experimental design

A randomized block design, summarized in Table 1, was used to minimize the high variability customarily seen in lumber mechanical properties. Two separate blocks were constructed to evaluate the effect of wood MC ranges and number of moisture cycles on various physical and mechanical properties of truss-plate joints. The two blocks were standard truss-plate joints and truss-plate joints with an adhesive applied at the tooth-wood interface.

Each block evaluated two factors: the severity of MC levels to which truss-plate joint specimens were subjected and the number of MC cycles. The severity of MC level was evaluated by subjecting 10 replicates for each factor to the following MC conditions: 1) held constant at 12 percent MC; 2) cycled between 9 and 15 percent MC; and 3) cycled between 5 and 19 percent MC. The rate at which subsequent moisture cycles degraded truss-plate joints was evaluated by subjecting 10 replicates to 0, 1, 2, 4, or 8 MC cycles. This made for a total of 150 truss-plate joint specimens per block (3 varying MC ranges × 5 possible numbers of MC cycles × 10 replicates/cell = 150 specimens). Although the material used to construct the replicates in the blocks was from different boards, the boards were chosen to have comparable specific gravity (SG) and stiffness values, thus allowing for a relative comparability between blocks.

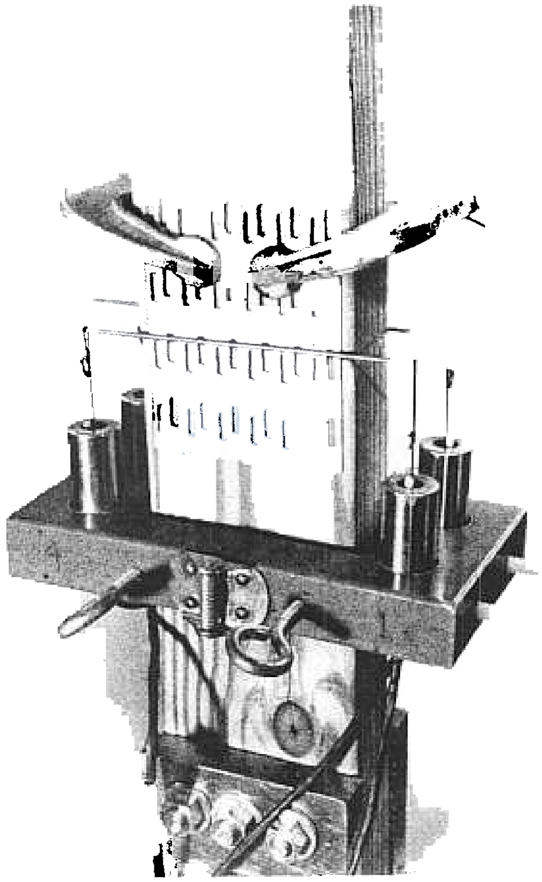


Figure 1. — Typical truss-plate joint used in this study, showing restraining clamps and LVDT.

Lumber and truss plates

The standard truss-plate joints were constructed with No. 2 grade KD15 southern pine lumber representing a narrow range of SG and modulus of elasticity (MOE). MOE of each board was estimated by measuring centerline deflection over a simple span. SG was based on volume at time of test. MC was determined on an approximately 1.5- by 1.5- by 3.5-inch block of wood removed adjacent to the truss plate after testing. Dimensions of the boards were nominal 2 by 4 inches by 18 feet in length. The boards were sampled from a local lumber retailer in central Louisiana.

To determine the effect of an adhesive interface, a second block of replicates was constructed that was similar in size and properties to the standard truss-plate joint block of replicates. Each block consisted of an equal amount of pith-associated and non-pith-associated lumber. The SG of the standard block was 0.488 and the MOE was 1.76×10^6 psi. The adhesive interface block had an SG of 0.485 and an MOE of 1.86×10^6 psi.

The die-punched truss plates used in this study were Gangnail GN20 type plates made of 20-gauge grade C sheet metal, 3 by 4 inches, with an average of 8.0 teeth per square inch, and an average tooth length of 0.360 inch.

Joint construction and testing

Figure 1 shows the standard truss-plate joint used in this study. In accordance with TPI-85 (26), all teeth were removed within a lumber end distance of 0.5 inch. The teeth were removed with a milling bit that cut the teeth at the plate surface. Thirty-six pairs of teeth were present in the upper member and 24 pairs of teeth in the lower member. This asymmetry ensured failure in the lower member, which was equipped with linear variable displacement transducers (LVDT).

An epoxy resin with a cure time of 15 minutes was applied with a sponge to the tips of the truss plate teeth immediately before pressing into the wood members preconditioned to an MC of 12 percent. An average of 0.0031 g of epoxy was applied to each tooth, with the resin spread along the tooth length during pressing. Truss plates were pressed into the wood members so as to make intimate contact but not so deeply that the plate surfaces became embedded in the wood.

After assembly, all 300 truss-plate joints were placed in a hygrothermally controlled standards room at 79°F and 66 percent relative humidity (RH) for about 4 weeks to allow for relaxation of stresses induced by pressing. After conditioning, 50 standard truss-plate joints and 50 adhesive-interface joints each were placed in one of three hygrothermally controlled units set to cycle between the following MC ranges: 9 to 15 percent, 5 to 19 percent, and a constant 12 percent. The conditions for the 9 to 15 percent moisture cycling ranged from approximately 100°F, 40 percent RH to 85°F, 85 percent RH. The MC conditions for the 5 to 19 percent moisture cycling ranged from approximately 110°F, 15 percent RH to 85°F, 95 percent RH, respectively. Ten standard truss-plate joints and 10 adhesive-interface truss-plate joints were removed from the hygrothermally controlled units at the completion of 0 (no cycling), 1, 2, 4, and 8 cycles and placed in the standards room for approximately 4 weeks before testing. The constant 12 percent specimens were held at a constant MC in the standards room for the same duration as the 0, 1, 2, 4, and 8 cycle specimens. The constant 12 percent MC specimens served as a control, allowing distinction between the effects of time and moisture cycling. Mid-depth MC was monitored during cycling with a handheld surface moisture meter. It should be noted that all moisture was atmospheric in nature; at no time were the joints exposed to direct surface water.

Loading was applied in tension by a 30,000-pound-capacity, screw-driven crosshead testing machine (Fig. 1). A constant displacement rate of 0.015 in./min. was applied to produce failure in 5 to 10 minutes. The specimen was attached to the testing machine with universal joints to eliminate potential moments produced by misalignment. The upper member was further restrained by the attachment of two C-clamps, which made end-matching of the wood blocks unnecessary. Joint slip was monitored by LVDT and load was monitored with a 10,000-pound-capacity load cell. Four simultaneous readings were taken every second from LVDT, located in pairs at the two opposite sides of the wood-wood juncture. These LVDT values were then averaged to provide overall slip values between the wood and plate. A computer-controlled data-acquisition system acquired the load and displacement readings.

Truss-plate backout is defined in this study as the dimensional difference between the wood member thickness and the wood-plus-plate thickness. This method was chosen to minimize errors caused by wood dimensional changes related to stress relaxation or MC. The wood-plus-plate thickness was measured after joint assembly and before tensile testing; the dimension was based on the average of two locations on each side of the long axis centerline of the truss plate and midway between the rows of teeth. Wood member dimensions were recorded at the same time.

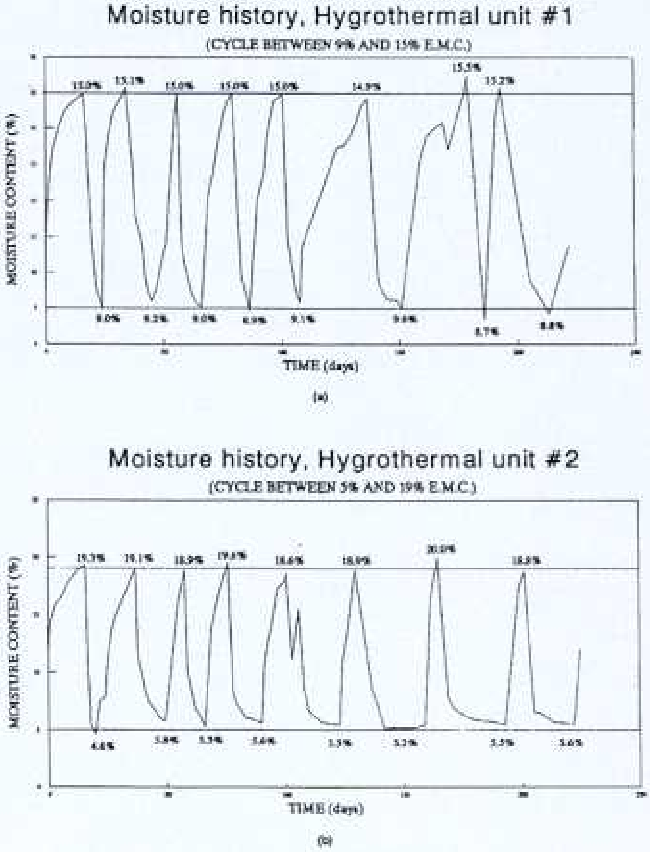
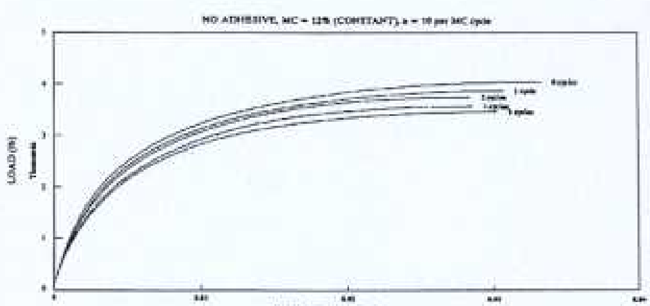


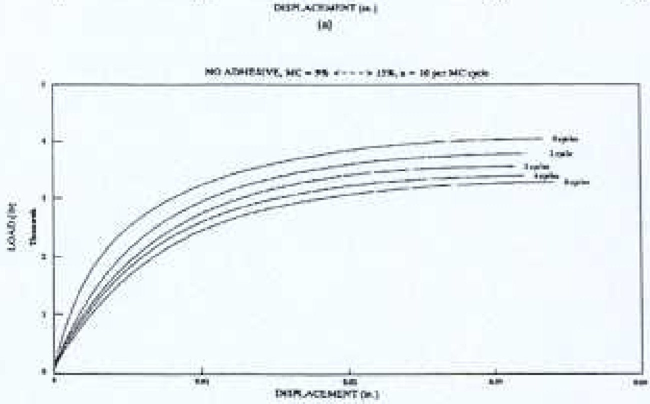
Figure 2. — Moisture history of truss-plate joints cycled between (a) 9 and 15 percent EMC; and (b) 5 and 19 percent EMC.

Results and discussion

The conditioning history of the moisture-cycled specimens is shown in Figure 2. The moisture history for the constant 12 percent MC specimens is not shown due to the lack of moisture fluctuations. The compressor motor needed maintenance during the sixth and seventh cycle in the mild cycle conditioning chamber, whereas compressor problems were encountered during the fifth cycle in the more severe cycle conditioning chamber. The duration of each moisture cycle varied with the operation of the conditioning chambers, and were coordinated to be of about equal length for both conditioning chambers.

Average load-slip traces for moisture-cycled truss-plate joints are summarized in Figure 3. Degradation of the truss-plate joint mechanical response attributable to factors other than moisture cycling is illustrated in Figure 3a. Although these truss-plate joints were kept in a standard conditioning room and did not undergo any significant moisture cycling, the rheological effects of localized wood relaxation surrounding





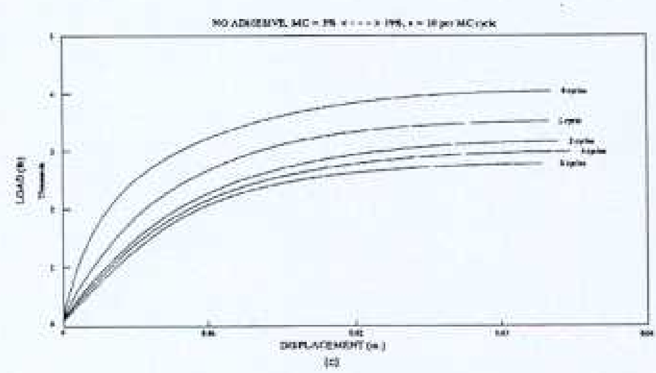


Figure 3. — Average load-slip traces for standard truss-plate joints subjected to 0, 1, 2, 4, or 8 cycles at the following MCs: (a) constant 12 percent; (b) between 9 and 15 percent; and (c) between 5 and 19 percent.

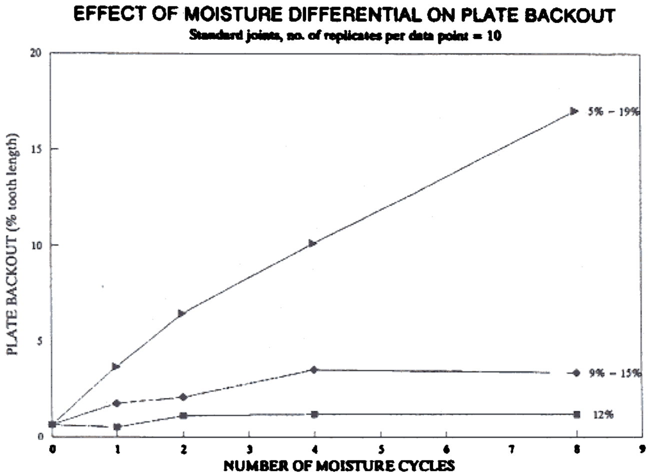


Figure 4. — Average plate backout values for standard truss-plate joints subjected to 0, 1, 2, 4, or 8 cycles at a constant 12 percent MC, cycled between 9 and 15 percent MC, and cycled between 5 and 19 percent MC.

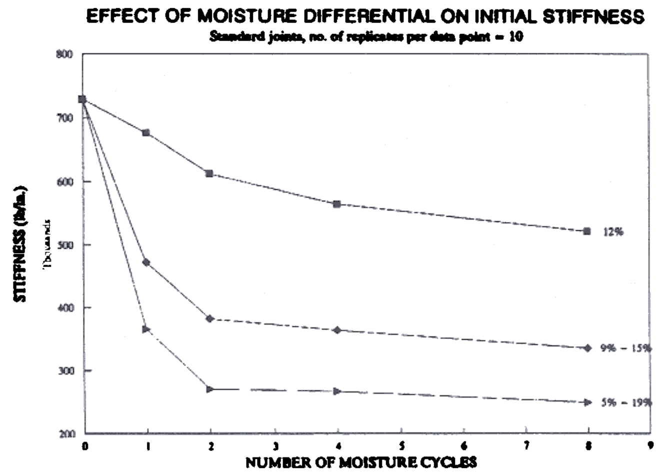


Figure 5. — Stiffness between 700 and 1,100 pounds for standard truss-plate joints subjected to 0, 1, 2, 4, or 8 cycles at a constant 12 percent MC, cycled between 9 and 15 percent MC, and cycled between 5 and 19 percent MC.

the teeth can be seen. Thus, even under ideal conditions, the truss-plate joints exhibited slightly diminished load-slip traces after post-assembly.

This reduction in mechanical behavior is magnified under conditions of moisture hysteresis (Figs. 3b and 3c). The first moisture cycle seems to have the greatest effect on truss-plate joint mechanical behavior, but subsequent moisture cycling continues to have a degradatory effect. This effect appeared to be leveling off with the mild moisture cycling but still had a rather significant impact on the severely moisture-cycled specimens.

The moisture hysteresis also appears to affect the fundamental manner in which stresses are transferred between the wood and truss plate. The time-dependent behavior of the data in Figure 3a shows that the load-slip traces change only in magnitude but not shape, as the traces are curvilinear from initial loading to failure. However, both the magnitude and shape of the load-slip traces in Figures 3b and 3c are altered by subsequent moisture cycles. The load-slip traces for moisture-cycled specimens are linear up to about 50 percent of the ultimate load, at which time the traces revert back to curvilinearity. The degree of linearity appears to be related to the severity of the moisture cycling, with the highest degree of linearity occurring in the most severely moisture-cycled specimens. Load-slip traces are most noticeably differentiated at low load levels, indicating a substantial decrease in initial joint stiffness for moisture-cycled specimens.

An alteration in the shape of the load-slip traces is most likely attributable to either a change in the interfacial contact between the wood and tooth or to backing out of the truss plate with subsequent moisture cycles. This finding seems consistent with the results of Chou (1), who found that load-slip traces of nails connecting plywood and studs are significantly altered by the presence of gaps between the plywood and stud. The mechanism of nail bending is analogous to that of tooth bending. Groom (9) modified Chou's model to accommodate boundary conditions more representative of a truss-plate tooth in a wood matrix, with results that support this finding.

Variability of the load-slip traces was most greatly affected by addition of the adhesive interface, with joints containing an adhesive interface being slightly less variable. Variability increased with the severity of the moisture cycling and the number of moisture cycles for both standard and adhesive-interface joints. Variability of the truss-plate joints will be covered in greater detail in a USDA Forest Service General Technical Report to be published at a later date.

Plate backout

Dimensional changes in lumber caused by moisture hysteresis have been shown in previous studies to cause truss plates to back out of wood (10,19,21,27). Plate backout as described in the previous studies was quantified in this study. Truss-plate joints subjected to a constant 12 percent MC backed out about 0.004 inch, which is the equivalent of about 1 percent of the total tooth length (Fig. 4), over a 10-month time frame.

In contrast, the first 9 to 15 percent MC cycle resulted in a plate backout of slightly less than 2 percent of tooth length. Subsequent mild moisture cycling resulted in some additional plate backout, which appeared to stabilize after the fourth moisture cycle at somewhere between 3 to 4 percent of tooth length. The more severe 5 to 19 percent MC cycling resulted in drastic plate backout. Truss plates backed out approximately 4 percent of tooth length after the first moisture cycle and continued to back out at an almost linear rate. Plate backout at the eighth and final moisture cycle was 0.045 inch, or about 17 percent of tooth length.

Joint stiffness

Figure 5 shows the effect of moisture hysteresis on the initial stiffness of truss-plate joints, measured between 700 and 1,100 pounds. Simple rheological effects can be seen in the specimens subjected to a constant 12 percent MC. Exposure to constant hygrothermal conditions resulted in a slow, steady decline of initial stiffness. Although the initial stiffness of standard specimens continued to decline even after eight moisture cycles, the rate of decline was small. Thus, the constant MC specimens seemed to stabilize at approximately 75 percent of the original stiffness.

Mild moisture cycling between 9 and 15 percent MC resulted in a much more abrupt decline in initial stiffness. The first moisture cycle resulted in a decrease in stiffness of 35 percent and the second cycle stiffness had decreased by 47 percent. Although there was a rapid decrease in initial stiffness in the mildly moisture-cycled specimens, the rate of decrease in stiffness slowed after several moisture cycles, with a lower limit appearing to be about 40 percent of the original stiffness. A similar but more degradative effect was seen with the more severe 5 to 19 percent MC cycles, in which stiffness decreased 50 percent after the first moisture cycle and stabilized at approximately 30 to 35 percent of the original stiffness. These results are consistent with those of Wilkinson (28), who showed that creep of truss-plate joints was sensitive to moisture cycling.

Comparison of plate backout (Fig. 4) and initial joint stiffness (Fig. 5) suggests that initial truss-plate joint stiffness is not fully explainable by plate backout. Large decreases in initial stiffness as a result of moisture cycling appear to be caused by plate backout and, either individually or in concert, by the localized relaxation of the wood surrounding the teeth and a reduction in the intimacy of contact between the wood and teeth. Wilkinson (30) noted that the elastic-bearing constant decreased 38 percent after one moisture cycle between 10 and 20 percent MC, suggesting that some localized relaxation may be occurring.

Ultimate load

The most important property of truss-plate joint mechanical behavior from a design standpoint is strength, which also seems to be significantly affected by moisture cycling (Fig. 6). The rheological effects on ultimate load of specimens that were subjected to a constant MC showed a net loss in strength of about 11 percent over a 9-month time frame. It appears that an upper limit of strength reduction for a constant MC would be approximately 20 percent, for a long-term strength of about 136 lb./tooth pair. However, this value is only an approximation, because the joints were continuing to degenerate.

The mild moisture-cycled specimens demonstrated a similar but magnified degenerative effect. Overall strength was reduced by almost 19 percent by the end of the eighth cycle. The upper limit of strength reduction for the mildly moisture-cycled specimens appears to be about 25 percent, or about 127 lb./tooth. Specimens cycled between 5 and 19 percent MC demonstrated an accelerated degradative response. An overall strength reduction of 31 percent after the eighth cycle was observed, which is comparable to the 27 percent reduction seen by McAlister (19) for 1-year outdoor exposure of truss-plate joints. The rate of the degradative response appeared to slow slightly with each subsequent cycle, but not enough that long-term response could be projected with any degree of reliability. Perhaps a similar experimental design conducted over a longer time frame would help define this upper limit.

It is worth noting that there is a relationship between the amount of plate backout (Fig. 4) and ultimate load (Fig. 6), suggesting that strength of truss-plate joints may be a function of plate backout.

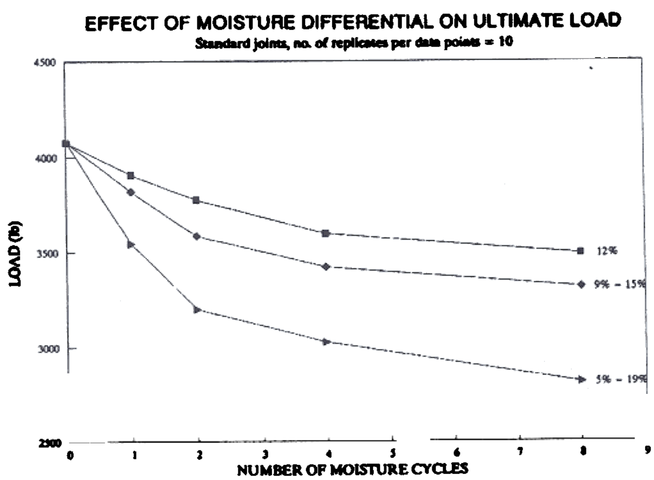


Figure 6. — Ultimate load for standard truss-plate joints subjected to 0, 1, 2, 4, or 8 cycles at a constant 12 percent MC, cycled between 9 and 15 percent MC, and cycled between 5 and 19 percent MC.

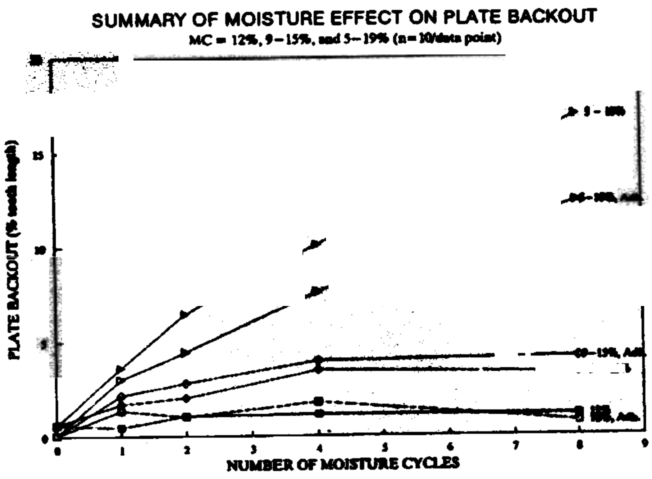
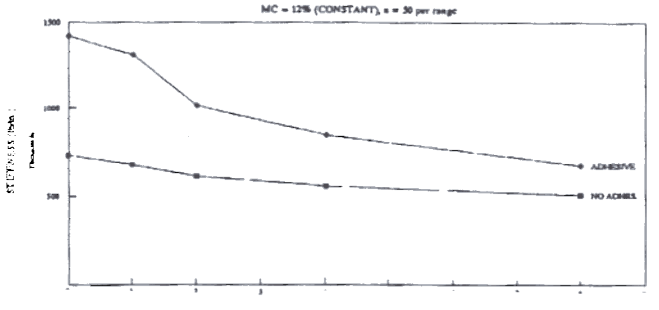
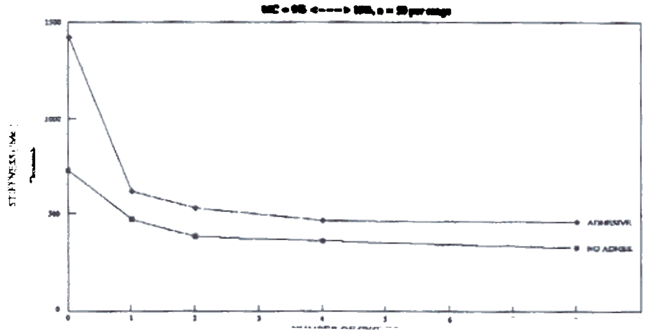


Figure 7. — Comparison of plate backout for standard truss-plate joints and truss-plate joints with adhesive subjected to 0, 1, 2, 4, or 8 cycles at a constant 12 percent MC, cycled between 9 and 15 percent MC, and cycled between 5 and 19 percent MC.



(a)



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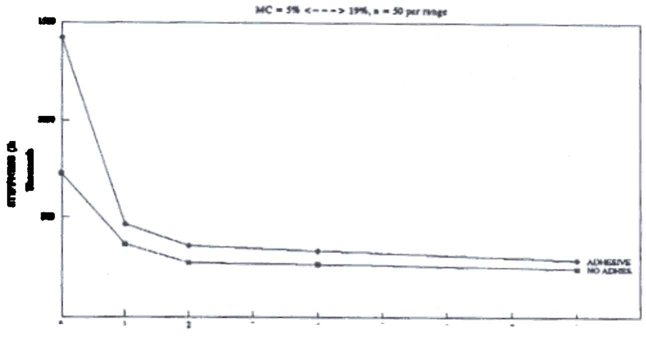


(c)

Figure 8. — Comparison of stiffness between 700 and 1,100 pounds for standard truss-plate joints and truss-plate joints with adhesive subjected to 0, 1, 2, 4, or 8 cycles at the following MCs: (a) constant 12 percent; (b) between 9 and 15 percent; and (c) between 5 and 19 percent.

All specimens in this study failed because of tooth withdrawal, demonstrating that the withdrawal forces exceeded the resistance to these forces. Not only do truss-plate joints with backed-out plates have less surface area with which to resist withdrawal forces, but the gap between the plate and the wood also produces withdrawal forces because of the eccentric transferal of stresses. Supportive evidence is given by Kanamori et al. (12), who showed that the withdrawal resistance of common nails in Japanese larch decreased by about half after five moisture cycles between approximately 8 and 15 percent MC.

Effect of adhesive between tooth and wood

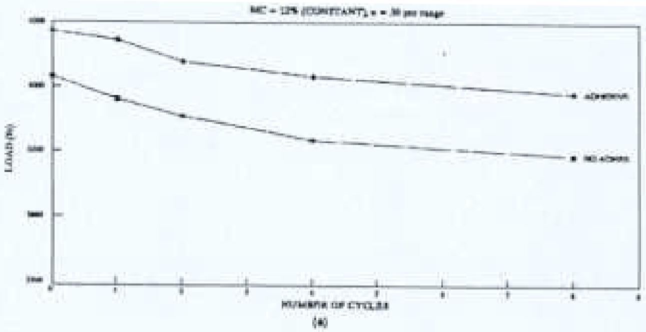
Sliker (25) has shown that an adhesive bond between the shank of a nail and wood increases the lateral load resistance by approximately 50 percent. Similar findings have also been reported for glued-bolted joints (23). Lambuth (15) also reported improved mechanical performance of truss-plate joints with the addition of an adhesive to the teeth immediately preceding assembly. Thus, a secondary objective of this study was to examine the effects of applying an adhesive interface between the teeth of the truss plate and the wood.

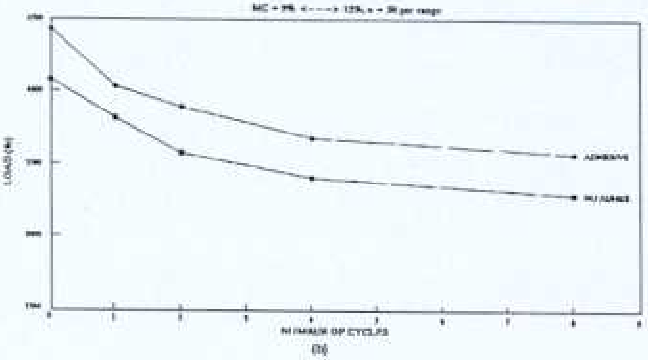
Plate backout for the truss-plate joints with and without an adhesive interface is summarized in Figure 7. The adhesive used in this study retarded plate backout in the specimens cycled between 5 and 19 percent MC, reducing backout from 17 percent of total tooth length to 12.5 percent. Thus, it appears that truss-plate joints subjected to large variations in MC may benefit from an adhesive interface between tooth and wood. Addition of the adhesive resulted in no discernible difference between the constant 12 percent MC specimens and the 9 to 15 percent MC specimens, primarily because of the small degree of backout.

Addition of an adhesive had the greatest effect on the stiffness of the truss-plate joints (Fig. 8). Although the stiffness of the truss-plate joints was initially increased by a factor of almost two, the gain in stiffness dissipated over time (Fig. 8a). The gain in stiffness was greatly affected by moisture cycling, with most of the increased stiffness being negated after the first moisture cycle. However, the adhesive did seem to add a permanent element that increased stiffness by some fixed amount. The degree to which the truss-plate joints were stiffened by the adhesive seemed to be inversely related to the severity of the moisture cycles, with the most severely moisture-cycled specimens exhibiting the least benefit.

Moisture cycling of truss-plate joints also has a significant effect on ultimate load (Fig. 9). Truss-plate joints with an adhesive tooth/wood interface degraded with successive moisture cycles at approximately the same rate as joints with no adhesive. However, application of the adhesive interface did increase the load-carrying capacity of the joints. As was the case with initial stiffness, the level of increase appears to be influenced by the severity of the moisture cycles, with the smallest increase under the most severe cycles.

It should be noted that the adhesive used in this study did provide adequate adhesion. However, visual examination of failed joints with an adhesive interface showed that approximately 5 percent of the surface of the teeth was covered with wood, indicating that a different adhesive system coupled with surface prepa-





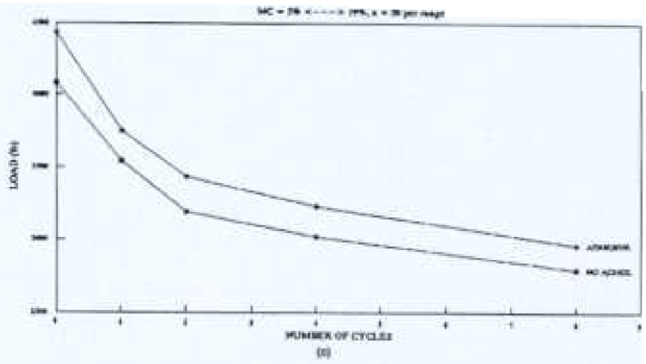


Figure 9. — Comparison of ultimate load for standard truss-plate joints and truss-plate joints with adhesive subjected to 0, 1, 2, 4, or 8 cycles at the following MCs: (a) constant 12 percent; (b) between 9 and 15 percent; and (c) between 5 and 19 percent.

ration of the truss plates would have resulted in additional adhesion and therefore increased mechanical properties.

The increase in mechanical properties for the adhesive-interface specimens is most likely attributable to a different stress transferal mechanism that takes advantage of the increased compatibility between the teeth and wood. This compatibility redistributes stresses so that stresses can be more effectively resisted by the wood. This is supported by other research that indicates that up to 90 percent of lateral load is supported by the first 25 percent of the tooth length (9). Additional factors that may explain the increase in mechanical properties are: adhesive action between the teeth and surrounding wood, increased tooth/wood contact area caused by diminished plate backout, and increased localized stiffness of the surrounding wood caused by impregnation of the wood cell by the epoxy.

Conclusions

Moisture cycling has a significant degradative effect on the mechanical behavior of truss-plate joints. Some degradation occurs from simple relaxation of the wood surrounding the truss-plate teeth, and this relaxation accelerates conditions of moisture cycling. This acceleration is magnified by plate backout, which was negligible for constant MC specimens, 5 percent of total tooth length for mildly moisture-cycled specimens, and 17 percent of total tooth length for severely moisture-cycled specimens. Mild moisture cycling resulted in a decrease of stiffness and strength of about twice that of constant MC specimens, and severe moisture cycling resulted in a decrease of about a factor of three. It should be noted that in-service loading may have a significant impact on the effect of moisture cycling, and that conclusions for actual trusses should be reserved until the development of models that couple loadings with environmental fluctuations.

Application of an adhesive to truss-plate teeth does appear to increase the compatibility between the teeth and surrounding wood, as demonstrated by a decrease in plate backout, an increase in initial joint stiffness, and an increase in ultimate load. The increase in initial joint stiffness caused by the adhesive was minimal after moisture cycling. However, the gains in ultimate load with the adhesive appear to be substantial regardless of the number and severity of moisture cycles. The improved performance of truss-plate joints with an adhesive interface is attributable to increased compatibility of truss-plate teeth and the surrounding wood; decreased plate backout, which results in increased tooth/wood contact area and better stress transferal; and possible impregnation of the surrounding wood, resulting in increased localized wood mechanical properties.

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